Anais da Academia Brasileira de Ciências (2018) 90(1): 471-478
(Annals of the Brazilian Academy of Sciences)
Printed version ISSN 0001-3765 / Online version ISSN 1678-2690
http://dx.doi.org/10.1590/0001-3765201720150509
www.scielo.br/aabc | www.fb.com/aabcjournal

Apparent digestibility of conventional and alternative feedstuffs by hybrid tambacu juveniles

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Manuscript received on July 21, 2015; accepted for publication on September 5, 2016

ABSTRACT

The apparent digestibility coefficients (ADC's) of dry matter (DM), crude protein (CP), and gross energy (GE) of conventional feedstuffs (cottonseed meal-CSM, soybean meal-SBM, wheat bran-WHB, corn-COR) and regional alternative feedstuffs (common bean residue meal-CBR, mesquite meal-MES, pasta by-product meal-PBM) were determined for hybrid juvenile tambacu *Colossoma macropomum* × *Piaractus mesopotamicus*. The apparent DM and GE digestibility of feedstuffs decreased ($p<0.05$) as fiber content of the ingredients increased. No differences ($p>0.05$) were found among ADC's of PBM and COR. The lowest CP ADC among energy sources was observed in MES; the lowest CP ADC among plant protein sources was observed in CBR. Information about the ADC's of conventional and alternative feedstuffs for tambacu is essential to formulate low-cost diets and can contribute to regional development.

Key words: Characin, fish nutrition, hybrid fish, nutritional value.

INTRODUCTION

The price and availability of the main feedstuffs used in fish diets affect the profitability of aquaculture. Thus, nutritionists are searching for alternative feedstuffs because these are essential to the expansion of sustainable aquaculture production. A good alternative to replace traditional feedstuffs in fish diets is the use of locally available new ingredients, especially in regions, such as northeastern Brazil, where the local production of ingredients does not satisfy domestic demand. This could reduce the competition that exists between livestock and aquaculture for conventional ingredients (mainly soybean meal and corn) and reduce feed cost.

Legumes are a traditional source of plant proteins for animal feed; currently, soybean meal is a major plant protein source in omnivorous

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fish diets (Pastore et al. 2012). However, beans and mesquite (*Prosopis* spp.) are also exploited in many countries in Latin America, Asia and Africa as human and/or animal food (Jones and Mejia 1999, Sawal et al. 2004). Among major food legumes, the common bean (*Phaseolus vulgaris* L.) is the third most important worldwide, superseded only by soybean and peanuts (*Arachis hypogea* L.) (Singh 1999). Brazil was the third world dry beans producer in 2014 (FAOSTAT 2016) and the first in the *Phaseolus vulgaris* (Jones and Mejia 1999). Though there are no current official data on the production of mesquite pods or seeds (*Prosopis juliflora*), this tree is found globally in rural areas with estimated availability of pods worldwide thought to be 2-4 million metric tons (Sawal et al. 2004). Additionally, one should not neglect the potential for animal consumption of residues in the human food industry. Pasta and bakery by-product are appointed as dietary corn replacer to different species, as pig (Prandini et al. 2016), dairy cattle (Schroeder 2012) and fish (Lawal et al. 2014, Silva et al. 2014). Brazil ranks third in the global production of pasta, producing more than 1.2 million tons in 2013 (IPO 2014). According Lopes et al. (2009), pasta by-product can represent to around 7% of the total products generated.

The determination of digestibility is the first step to evaluate the potential of an ingredient for use in aquafeeds. However, species-specific information regarding the digestibility of several feedstuffs is necessary, due to differences in digestive physiology of each species (Tram et al. 2011).

According to the Brazilian Institute of Geography and Statistics, Brazilian aquaculture produced 483,241 tons in 2015. Of this amount, 7.7% (37,443 ton) were hybrids of tambaqui (*Colossoma macropomum*) and *Piractus* species (*P. mesopotamicus* and *P. brachypomus*) (IBGE 2016). Despite the economic importance of hybrid fish from indigenous species in Brazil, their nutritional requirements have been neglected. No previous study has surveyed the apparent digestibility of feedstuffs for Brazilian fish hybrids, such as tambacu (*C. macropomum* × *P. mesopotamicus*).

Thus, this study was conducted to determine the apparent digestibility coefficients (ADC's) for dry matter, crude protein and energy of alternative and conventional feedstuffs for hybrid juvenile tambacu.

MATERIALS AND METHODS

The alternative feedstuffs were selected based on the volume of production and regional (Northeast) availability and consisted of: common bean (*Phaseolus vulgaris*) residue meal from grains rejected by industry (e.g. broken, with insect larvae) after post-harvest operations, mesquite (*Prosopis juliflora*) meal manufactured from whole pods collected from trees of wild Caatinga vegetation, pasta by-product composed from broken parts commercially unviable to the human consumer market. Common bean residue and pasta by-product were provided by small local manufacturers (Garanhuns-PE). The conventional feedstuffs evaluated were: corn, soybean meal, wheat bran, and cottonseed meal; these were purchased from a local supplier (Rancho Alegre®, Garanhuns, PE) and showed a commercial standard. The chemical composition of the evaluated ingredients is shown in Table I.

The practical reference diet (Table II) was formulated (30% CP; 3,400 kcal DE kg^{-1}) considering the pacu nutrient requirement (Bicudo et al. 2010) due to the absence of information about tambacu requirements. Test diets were formulated combining 70% of basal diet and 30% of each test ingredients, added of 0.1% chromic oxide (Cr_2O_3) as inert marker. Before the diet was manufactured, all ingredients were finely ground (0.8-mm particle size) in a hammer mill, weighed, mixed, moistened with 20% water (%v:w), and pelleted in a mincer.

TABLE I
Chemical composition (dry matter basis) of evaluated ingredients.

	Mesquite meal	Pasta by-product	Wheat bran	Corn	Cottonseed meal	Common bean residue	Soybean meal
Dry matter (%)	95.6	89.8	92.8	91.3	95.6	95.5	91.0
Crude protein (%)	9.7	14.3	17.8	10.0	27.2	24.3	50.3
Gross energy (kcal/kg)	4,009	2,879	4,221	3,828	4,840	4,139	4,234
Ether extract (%)	2.5	2.6	7.2	10.5	11.5	3.2	4.2
Nitrogen free-extract (%)[1]	67.7	81.5	60.5	73.1	24.5	53.2	32.6
Crude fiber (%)	16.2	0.3	9.7	4.1	32.6	14.8	6.3
Ash (%)	3.9	1.3	4.8	2.3	4.2	4.5	6.6

[1]Calculated by (100 – crude protein – ether extract – crude ash – crude fiber).

TABLE II
Ingredients and chemical composition of reference diet.

Ingredients	(%)
Wheat bran	37.00
Soybean meal	21.50
Fish meal	17.50
Corn starch	14.07
Corn	5.00
Soybean oil	2.31
Vitamin-mineral premix[1]	2.50
Chromic oxide	0.10
BHT[2]	0.02
Chemical composition (dry matter basis)	
Ether extract (%)	6.00
Crude fiber (%)	6.3
Available phosphorus (%)	0.81
Ash (%)	8.48
Dry matter (%)	95.0
Digestible energy (kcal/kg)	3,428
Crude protein (%)	29.9

[1]Contains (quantities kg^{-1} premix): vitamins A = 1,000,000 UI; D3 = 312,500 UI; E = 18,750 UI; K3 = 1,250 mg; B_1 = 2,500 mg; B_2 = 2,500 mg; B_6 = 1,875 mg; B_{12} = 4 mg; ascorbic acid = 31,250 mg; niancin = 12,500 mg; calcium pantothenate = 6,250 mg; biotin = 125 mg; folic acid = 750 mg; choline = 50,000 mg; inositol, 12,500 mg; minerals: iron sulfate = 6,250 mg; copper sulfate = 625 mg; zinc sulfate = 6,250 mg; manganese sulfate = 1,875 mg; sodium selenite = 13 mg; calcium iodate = 63 mg; cobalto sulfate = 13 mg. [2]BHT, butylated hydroxytoluene.

Diets were then dried in a forced ventilation oven (50ºC; 24 h) and dried pellets were stored at 4ºC until use.

Juvenile tambacu (17.6±2.1 g) were stocked in cylindrical plastic cages (60L; 11 fish per cage), then placed in 150-L circular polyethylene tanks (one cage per tank) kept indoors in a recirculating system with constant aeration. The water quality parameters were measured daily: temperature (27.3±0.3ºC), dissolved oxygen (8.1±0.3 mg/L) and pH (6.4±0.2). All water parameters remained within acceptable values for tambacu, considering the parental species requirements (Araújo-Lima and Gomes 2005, Urbinati and Gonçalves 2005).

Fish were fed their respective diets for a 3-d acclimation period followed by fecal collection period. Fish were hand-fed to apparent satiety in four daily meals (8:00, 11:00, 14:00 and 17:00h). Feed wastes were carefully monitored and prevented using visual cues. One hour after the last daily meal, the fish were transferred in cages into 200-L cylindrical-conical digestibility tanks equipped with aeration systems, temperature controls, and refrigerated plastic bottles for feces collection. Feces were collected after 12h overnight (6pm to 6 am) by sedimentation, oven-dried (55ºC; 24h), grinded and stored under refrigeration (-15ºC) for posterior analysis.

Chemical composition of the diet, feedstuffs and feces was determined according to standard (AOAC 2000) recommendations. Apparent digestibility coefficients for test diets ($ADCN_D$) were calculated according to equation described by (Cho et al. 1982):

$$ADCN_D = 100 - \left[100 \left(\frac{\%Cr_2O_{3d}}{\%Cr_2O_{3f}} \right) \times \left(\frac{\%N_f}{\%N_d} \right) \right]$$

where $ADCN_D$ = ADC of a nutrient in the test diets, Cr_2O_{3d} = chromic oxide in the diet, Cr_2O_{3f} = chromic oxide in the feces, N_f = nutrients in feces and N_d = nutrients in the test diets.

The apparent digestibility coefficients of nutrients from each ingredient ($ADCN_I$) were calculated using the following equation (Forster 1999):

$$ADCN_I = \left[\frac{(a+b) \times ADCN_T - a \times ADCN_R}{b} \right]$$

where: a=nutrient contribution of reference diet to nutrient content of test diet, b=nutrient contribution of test ingredient to nutrient content of test diet, (a + b)=level of nutrient in combined diet (%), $ADCN_T$=apparent digestibility coefficient of a nutrient in the test diet, and $ADCN_R$=apparent digestibility coefficient of a nutrient in the reference diet

The trial was set up in a totally randomized experimental design, with seven treatments and three replicates. Results were submitted to statistical analysis of variance (ANOVA). Means showing significant differences ($p<0.05$) between treatments were compared by Tukey's test.

RESULTS

There was a significant ($p<0.05$) difference in apparent digestibility (ADC) of dry matter (DM), crude protein (CP) and gross energy (GE) of ingredients by tambacu juveniles (Table III).

The ADC of DM was highest (>80%) in corn, pasta by-product, and soybean meal, although there was no significant difference ($p>0.05$) among these feedstuffs. The mesquite meal was the ingredient that registered the lowest value (27.0%) of DM digestibility and was significantly different ($p<0.05$) of all ingredients evaluated.

The high protein digestibility values (>85%) was observed for five feedstuffs (pasta by-product, wheat bran, corn, cottonseed meal and soybean meal) evaluated. Mesquite meal registered CP digestibility that was significantly lower (27.0%) than that of common bean residue (66.3%).

There was a significant difference ($p<0.05$) in ADC of GE (40.2-93.3%) among the ingredients tested. The higher energy digestibility was obtained in corn, but was similar ($p>0.05$) to pasta by-product.

TABLE III
Apparent nutrients and energy digestibility coefficients (%) of different feed ingredients for tambacu juveniles.

	Apparent digestibility coefficients (%)				
	Dry matter	Crude protein	Gross energy	Digestible energy (kcal/kg)[1]	Digestible protein (%)[1]
Mesquite meal	27.0[a]	26.7[a]	40.2[a]	1,612	2.6
Pasta by-product	89.7[d]	95.7[c]	84.6[de]	2,436	13.7
Wheat bran	66.7[c]	97.3[c]	55.9[bc]	2,360	17.3
Corn	90.0[d]	94.0[c]	93.3[e]	3,572	9.4
Cottonseed meal	51.7[b]	85.7[bc]	56.5[c]	2,735	14.1
Common bean residue	55.3[b]	66.3[b]	46.6[ab]	1,929	13.4
Soybean meal	84.3[d]	90.3[c]	78.6[d]	3,328	45.4
Coefficient of variation (%)	10.2	9.3	5.3	-	-

Values are means of three replicates, and values within the same column with different superscript letters are significantly different ($p \leq 0.05$). [1]Dry matter basis.

DISCUSSION

There are similarities between the CP ADC observed for soybean meal in this study and those described for other omnivorous species, such as tambaqui (Vidal Júnior et al. 2004), pacu (Abimorad et al. 2008), jundia (Oliveira Filho and Fracalossi 2006), and tilapia (Guimarães et al. 2008, Zhou and Yue 2012). In contrast, Fernandes et al. (2004) registered lower CP digestibility (75.9%) for soybean meal made from pirapitinga *P. brachypomus*. Soybean meal showed superior nutritional value for CP as compared with the other legume meals evaluated (common bean and mesquite) and cottonseed meal. These differences can be explained in part by the presence of anti-nutritional factors and fiber content in feed.

In the present study, the use of raw common bean residue resulted in ADC of DM, GE and CP lower than that registered for Nile tilapia and black tiger shrimp *Penaeus monodon*, respectively, feed with soaked + roasted lima bean *P. lunatus* (Fagbenro 1998) and autoclaved only or autoclaved germinates black gram *P. mungo* (Kumaraguru Vasagam and Rajkumar 2011). In contrast, the inclusion of 40% raw black gram does not decrease CP ADC in cyprinid rohu *Labeo rohita* (Ramachandran and Ray 2007).

The presence of anti-nutritional factors (e.g. trypsin inhibitors, alkaloids, tannins, hemagglutinins) in legumes seeds has been known to negatively affect their use such as alternative protein source (Francis et al. 2001). Galán et al. (2008) registered concentrations of trypsin inhibitor in *P. juliflora* meal that were 20 times higher (9.32 units of trypsin inhibited/mg dry matter) than those in meal from three other species of *Prosopis* fruit (0.29 to 0.49 units of trypsin inhibited/mg dry matter). Comparatively, trypsin inhibitor activity in Brazilian varieties of common beans ranged from 23.1 to 27.6 units of trypsin inhibited/mg (Jourdan et al. 2007). Nevertheless, in the present study, nutritional value of protein from common bean meal was significantly higher than mesquite meal. A possible explanation for this might be that *P. juliflora* seeds are rich in mesquite gum (galactomannans) (Chaires-Martínez et al. 2008). Previous research suggested that galactomannans decrease the availability of nutrients and growth of others species (Hossain et al. 2003, Sawal et al. 2004, Bhatt et al. 2011).

Ingredients containing higher levels (14.8-32.6%) of crude fiber, such as common bean residue, mesquite meal, and cottonseed meal showed low values of DM, CP, and GE ADC.

Likewise, previous studies have reported a negative correlation between fiber content of the diet and ADC of DM, CP and GE of fish (Tram et al. 2011, Guimarães et al. 2012, Zhou and Yue 2012).

Among the ingredients evaluated, corn and pasta by-product showed the highest and similar ($p>0.05$) ADC's for DM, CP, and GE. The GE digestibility coefficient (93.3%) of corn was higher than that those reported for some round fish species, such as pacu (75.8%) by Abimorad et al. (2008), pirapitinga (57.6%) by Vásquez-Torres et al. (2013) and tambaqui (75.0%) by Gutierrez et al. (2009). This result is in agreement with findings reported by Abimorad et al. (2007) that showed that pacu is capable of digesting and absorbing relative large amounts of carbohydrates.

Studies on the utilization of pasta by-product residue in poultry and broiler chicks have indicated that this ingredient is a potentially useful feed ingredient (Nunes et al. 2001a, b). In the present study, corn and pasta by-product showed similar ADC's. Therefore, the pasta by-product showed potential as corn replacer in diets to tambacu juveniles. However, compared to mesquite meal these energetic ingredients were superior, although nitrogen free-extract values were near among ingredients.

Among the plant protein sources tested, soybean meal was digested more effectively than cottonseed meal and common bean residue meal, showing that tambacu juveniles have low capacity to digest ingredients with high fiber and anti-nutritional factor content. In general, ADC's of conventional feedstuffs were equivalent compared to parental species. These findings are important for the development of low-cost and balanced rations made from regionally available residues and ingredients for tambacu juveniles.

ACKNOWLEDGMENTS

This research was funded by Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq; Project nº 475841/2009-3). The authors are indebted to Comissão Executiva do Plano da Lavoura Cacaueira (CEPLAC) for providing the fish and Fundação de Amparo a Ciência e Tecnologia do Estado de Pernambuco (FACEPE) for scholarship to the second author.

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